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The Effect of Fire on the Community Structure of Macro-Invertebrates in a Compartmentalized Wetlands Ecosystem

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Problem Statement: **How does fire in a seasonally aquatic ecosystem affect the species density and species richness of macro-invertebrates through seasonal variations, compared to the species density and species richness in a seasonally aquatic ecosystem that did not experience the disruption of a wildfire?**

Abstract

The Everglades is a unique wetland ecosystem and has been negatively impacted by anthropogenic activities. It is currently the target of expensive conservation efforts to restore it to its original state. A major aspect of this restoration is the reestablishment of hydrologic connectivity across the ecosystem.

It has been suggested that levees and drainage canals, which cause hydrologic and habitat discontinuity and compartmentalization, affect the burning patterns of wetlands. Fires are now occurring more often than historically, and are increasingly detrimental to the ecosystem. Everglades' macro-invertebrate communities, which are critical components of the food web, can be used as indicators of the effects of fire on a compartmentalized wetland.

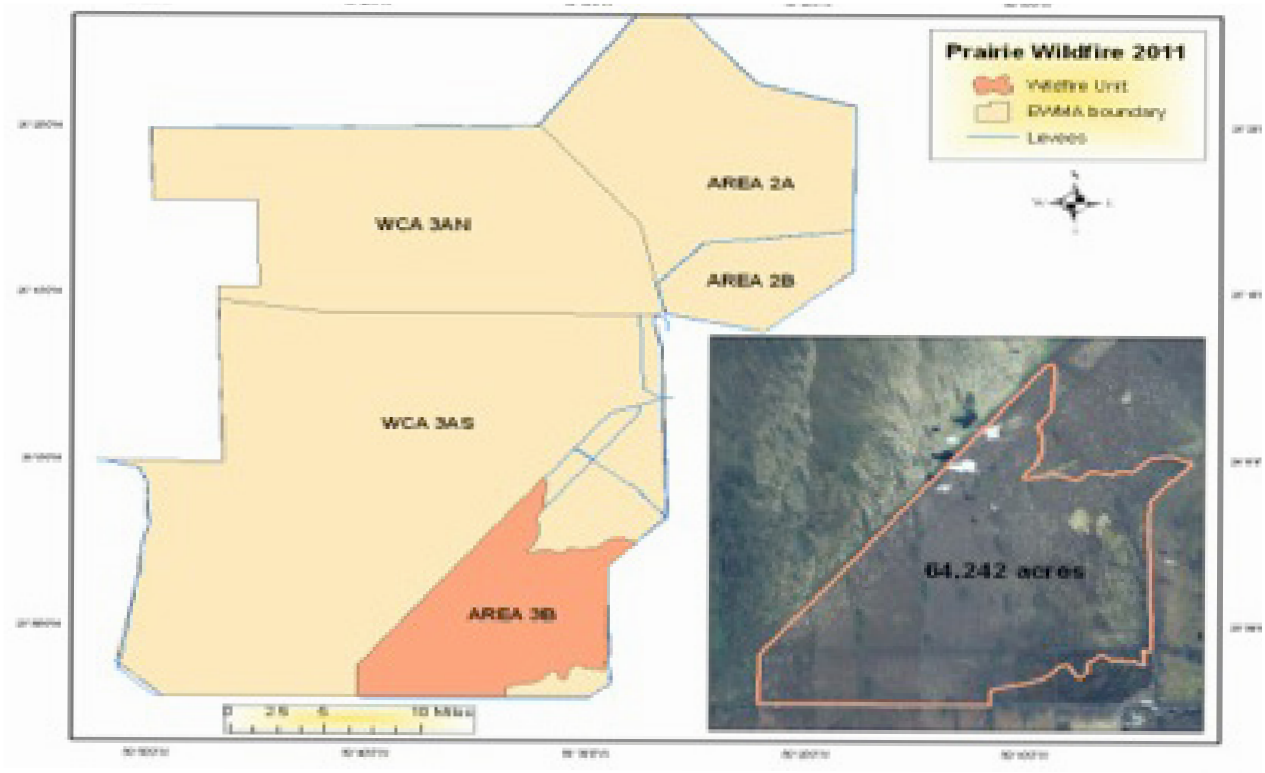
The purpose of this study was to evaluate the effects of fire on the community structure of macro-invertebrates in areas of the central Everglades. Using throw-trap and sweep surveys, invertebrates were collected in three restoration sites before and after these sites were disturbed by wildfire in June 2011. Invertebrates were also collected before and after June 2011 in two sites that did not experience a fire.

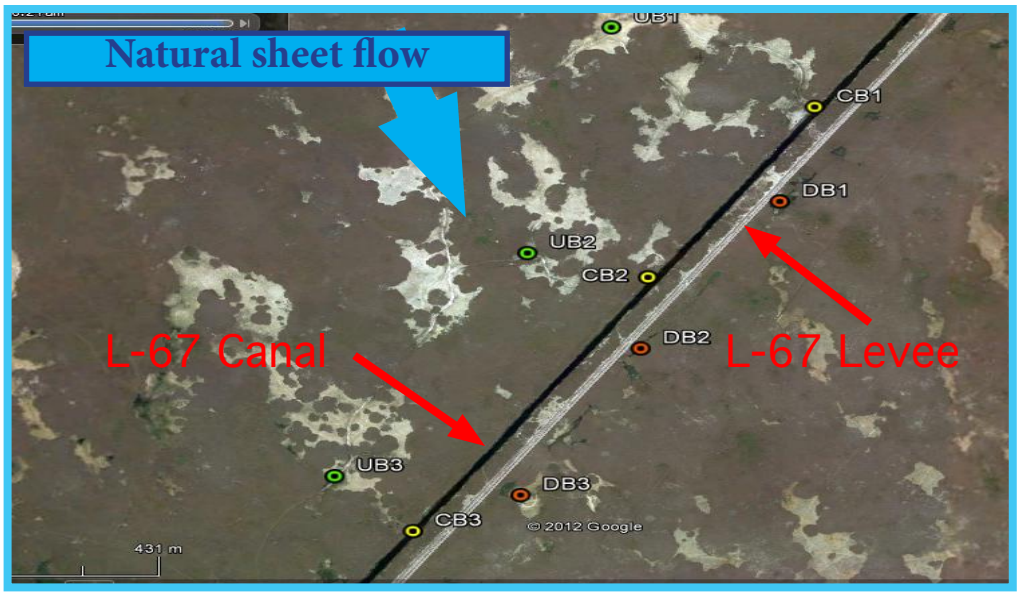
The results demonstrate that fire may have a significant impact on species richness and density of macro-invertebrates in the compartmentalized wetland ecosystem. This suggests that the severity of droughts, and consequently the severity of fires, need to be controlled to maintain proper balance of the ecosystem. These findings support the continued need for aggressive restoration efforts, which include removal of canals and levees to restore hydrologic connectivity to wetlands.

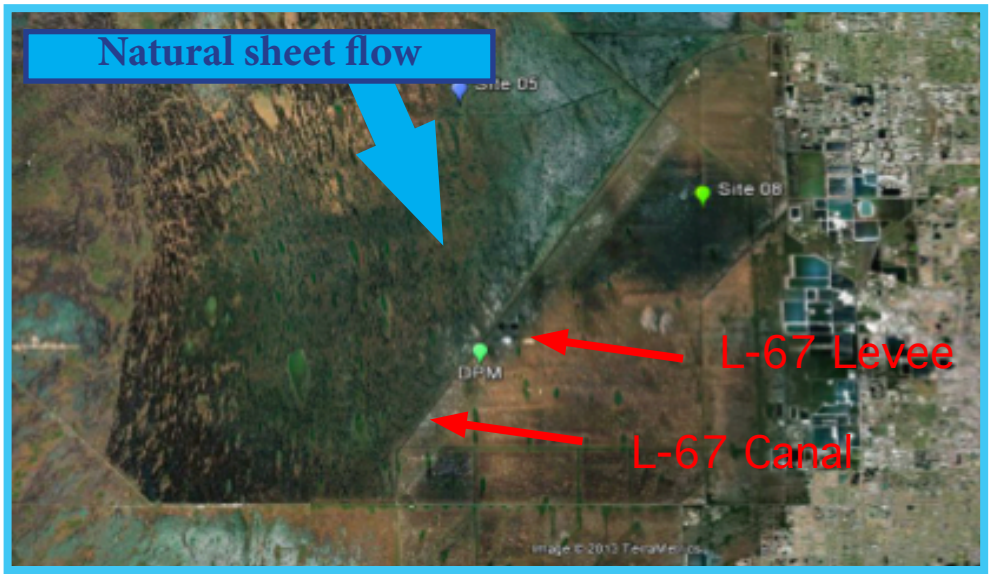
What is so special about South Florida's Wetlands and what has been done to protect them?

As a result of its unique characteristics, the Everglades have been the focus of major

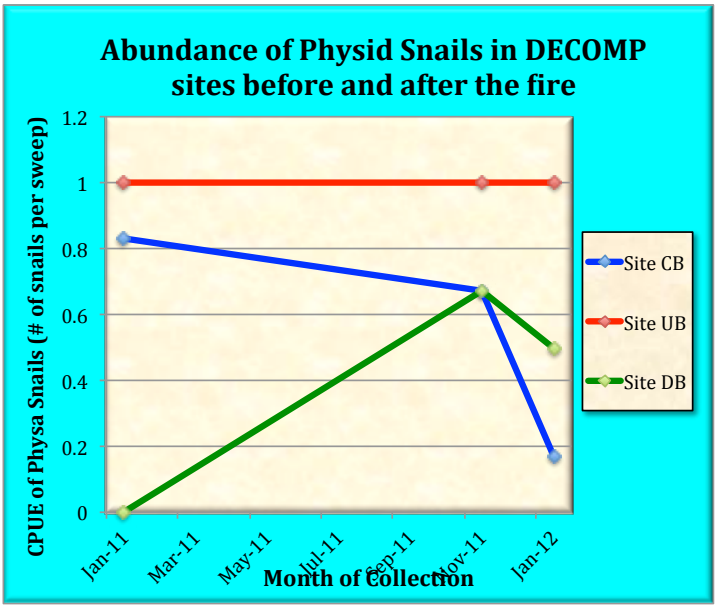
Image courtesy of M. Ward, Biologist, FFWCC

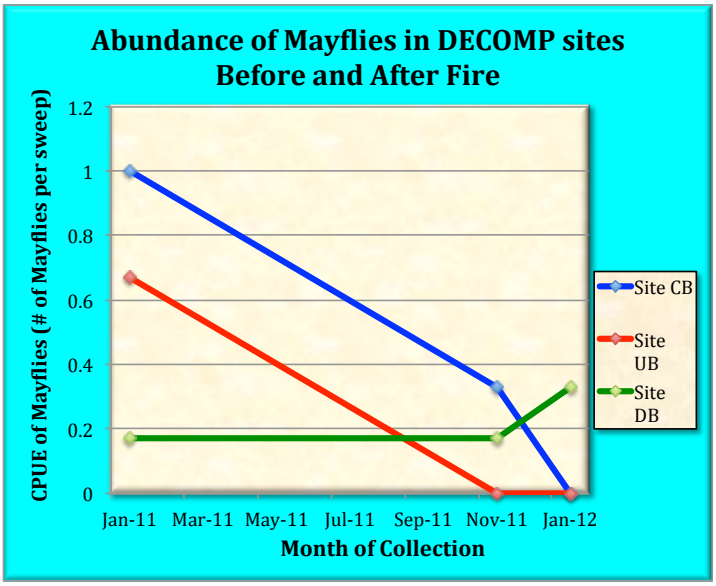






Sweep Data





restoration efforts for many years. The Comprehensive Everglades Restoration Plan (CERP) was created in 2000 to try to restore the natural flow of water through the Everglades and to improve the quality of the water in Lake Okeechobee. It is expected to cost at least $10.5 billion and to take more than 35 years. The DECOMP Project is an extension of CERP, focused on reducing compartmentalization of the Everglades through the Water Conservation Areas (WCA) and into Everglades National Park. Decompartmentalization entails removing constructed canals, levees and other barriers that impede the natural sheet flow of water into and through the historic Everglades and restoring a more natural water flow. It will be used as a test run to predict the outcome of CERP as it will provide environmental engineers with an indication of how to proceed with the future restoration of these compartmentalized wetlands.

What role do wildfires play in seasonally aquatic Ecosystems?

Although wildfires are historically beneficial to most ecosystems when they occur periodically and moderately, the compartmentalization of levees and drainage canals that cause hydrologic and habitat discontinuity affect historic burning patterns of wetlands. Statistics show that in the Everglades, fires and droughts are now occurring more often than is natural, and are becoming increasingly more detrimental to the compartmentalized ecosystem.

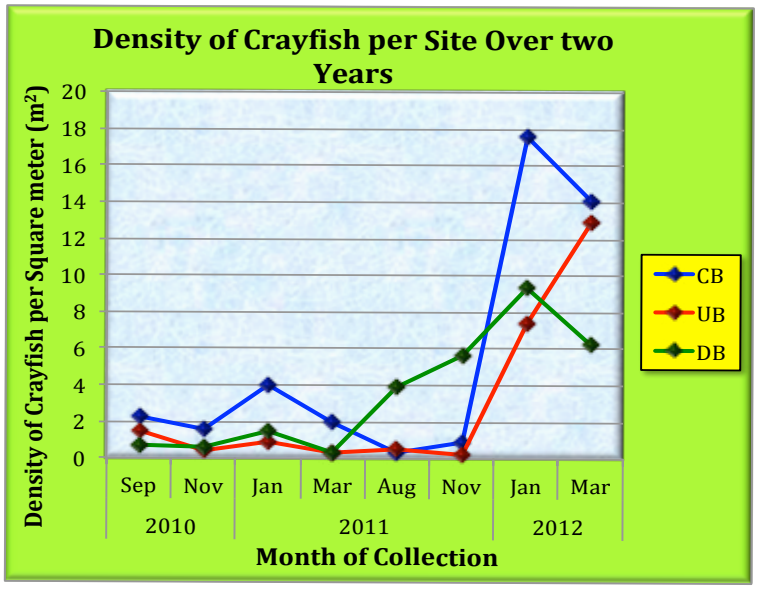
In June 2011, a large and uncontrolled fire, stemming from a prolonged drought swept through the Water Conservation Areas of the Everglades, which are being used as DECOMP sites, and burned nearly everything in it's path. The aftermath drastically delayed DECOMP plans to begin removing part of the levee of the L67A canal.

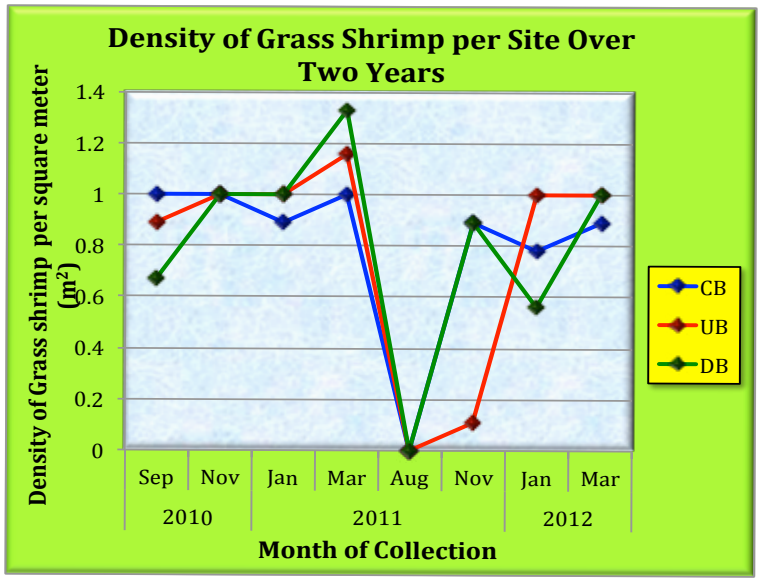
Why are invertebrate communities significant to wetlands restoration research?

The Everglades invertebrate community serves as a basal part of the ecosystem, is very sensitive to hydrological conditions and productivity levels and is found in virtually all freshwater wetlands. Top predators such as wading birds are directly dependent on prey density, which consists of mostly invertebrates. These factors enable the invertebrate community to serve as an indicator of the impact of hydrological alteration on aquatic faunal communities.

Droughts have a significant impact on aquatic invertebrate communities; as the marsh dries, its sur-

Throw trap data



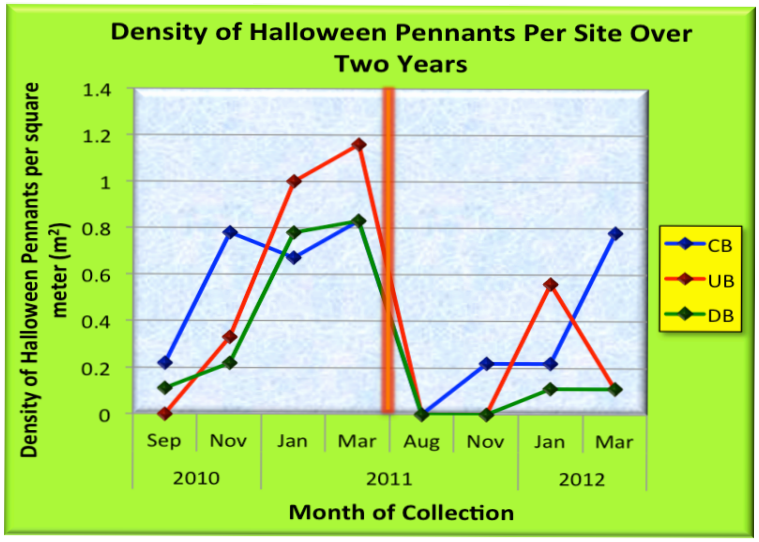


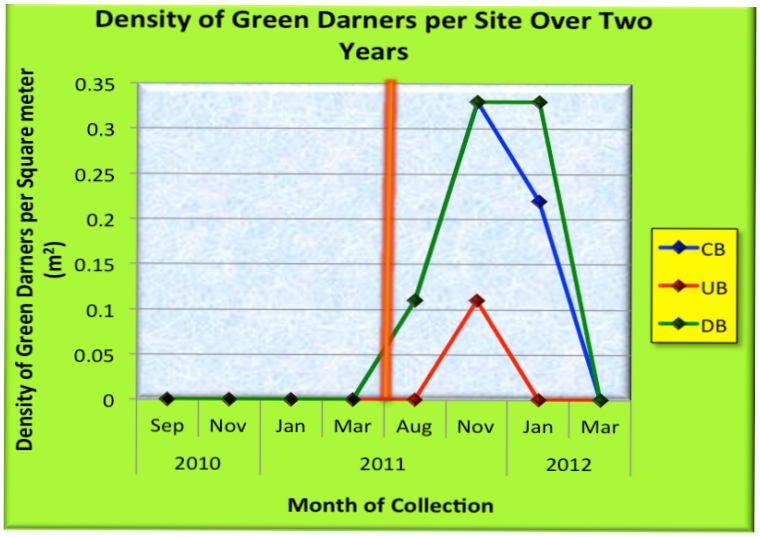
face is exposed eliminating habitat for aquatic animals and causing high mortality of most species. Additionally, water management actions (construction of canals and levees) leading to increased drought frequency and severity lengthen the time required for fish and crustaceans to recover to levels considered representative of the historical Everglades. In addition, Indices of productivity (biomass) of crayfish and grass shrimp play a prominent role in most RECOVER Conceptual Ecological Models and in CERP Interim Goals because they are prey for wading birds. This has lead to the Trophic Hypothesis for Everglades Restoration, which states that re-creation of historical linkages between rainfall and hydrology will restore dynamics of small-fish and crustacean communities, permitting recovery of historic levels and locations of wading bird nesting.

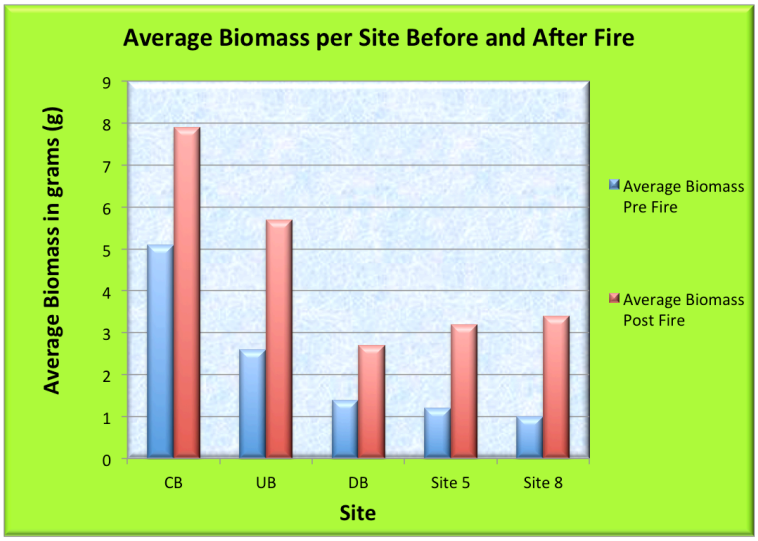
The purpose of this study is to determine the effects of fire (specifically the fire of June 2011 in the Water Conservation Areas that was brought on by an elongated drought) on the community structure, as measured by species density and richness, of the macro-invertebrate community in the Everglades Water Conservation Areas, which are soon to be restored by the DECOMP project. A significant effect would support the continued need for removal of canals and levees to restore hydrologic connectivity to wetlands.

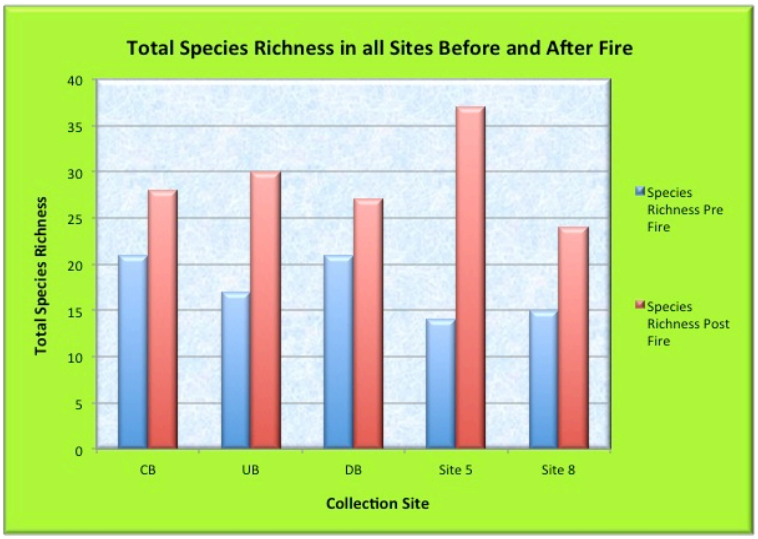
Results

The SIMPER and ANOSIM analysis, which de-









termine changes in community composition and whether or not they were significant, showed that DECOMP as a whole as well as the DB site had significant changes ($p<0.05$) in invertebrate community structure from before to after the fire. The other two DECOMP sites, CB and UB, did not individually have a significant change in community composition ($p>0.05$). Both the reference sites, sites 5 and 8, also experienced significant changes in community composition ($p<0.05$). nMDS Plots were created to show changes in community structure over time.

The SIMPER and ANOSIM analysis of Community composition for sweeps showed that the smaller invertebrate community structure of DB significantly changed ($p<0.05$). The community composition of UB and CB sites did not significantly change before and after the fire ($p>0.05$).

Crayfish density per square meter increased in all DPM sites in months after the fire. Grass shrimp were strongly impacted by the disturbances of the drought and fire, as their density per square meter plummeted sharply in all DPM sites after the fire. Their numbers are now showing a trajectory of recovery to pre-fire levels. Halloween Pennant density per square meter in the DPM sites decreased after the fire. There is a variable recovery rate between the sites; the numbers in DB are still low after the fire. Density of larval green darners experienced a strong increase and then a strong decrease in all DPM sites after the fire.

CPUE of mayflies (Ephemeroptera) decreased after the fire in CB and UB, but in DB they slightly increased. Physid Snails (Haitia spp.) exhibited variable responses in CPUE between sites. UB remained constant, DB increased, and CB appeared to decrease.

Conclusions

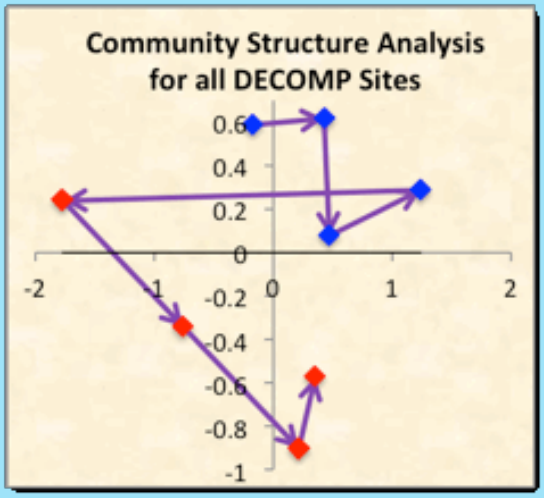
This study was conducted to investigate how fire that stems from a drought in a seasonally aquatic ecosystem affects macro-invertebrate community composition. My hypothesis stated that the sites affected by fire would have a significant change in invertebrate community structure and would see an overall decrease of invertebrate species richness and species density. I also predicted that the reference sites, those that were not affected by fire, would not vary significantly in community composition. The SIMPER and ANOSIM statistical analyses supported the hypothesis that the invertebrate community in the DPM sites as a whole changed significantly from before the fire to after. Interestingly, it also showed that there was a significant difference in the invertebrate community structure of only one of the DPM sites, site DB, which was consistent with the sweep data. The species richness of DB actually increased and the density of individual invertebrates varied. The community structure in the other two DPM

Analysis of Invertebrate Community Structure Before and After Fire (throw traps)		
Site	**Average Simper Dissimilarity**	**P value**
CB	39.27	0.286
UB	50.37	0.171
DB	54.08	0.029
DMP TOTAL	37.02	0.029
Site 5	73.64	0.018
Site 8	63.93	0.029

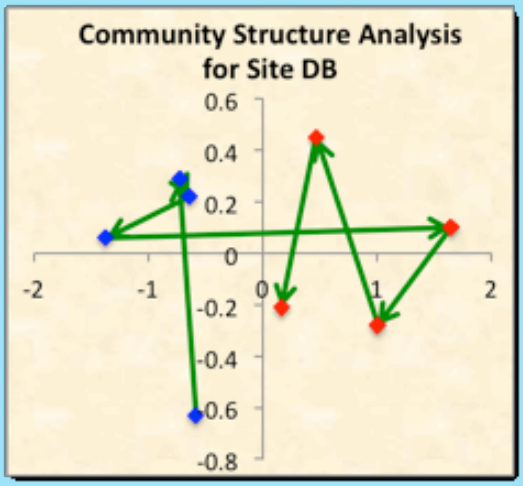
Analysis of Invertebrate Community Structure Before and After Fire (sweeps)		
Site	**Average Simper Dissimilarity**	**P Value**
CB	59.57	0.524
UB	37.1	0.238
DB	54.54	0.024
DPM TOTAL	51.08	0.454

Kruskal-Wallis analysis of Invertebrate Biomass for all sites Before and After Fire	
Site	**P value**
CB	0.936
UB	0.107
DB	0.003
Total DMP	0.015
Site 5	0.002
Site 8	$P < 0.001$

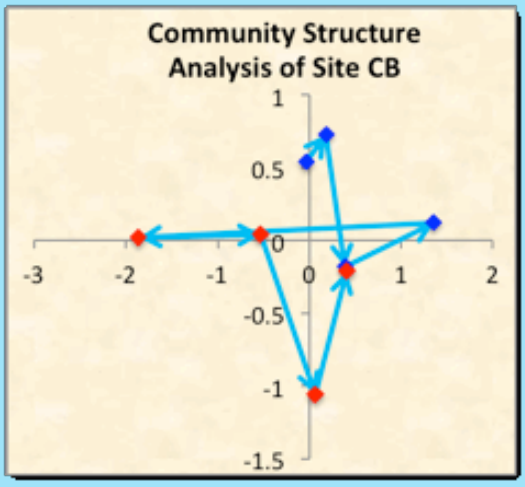
nMDS Coordinates of DECOMP As a Whole		
Sample	X	Y
10-Sep	-0.17	0.59
10-Nov	0.43	0.62
11-Jan	0.47	0.08
11-Mar	1.24	0.29
11-Aug	-1.77	0.24
11-Nov	-0.76	-0.34
12-Jan	0.22	-0.9
12-Mar	0.35	-0.57



nMDS coordinates of Site DB		
Sample	X	Y
10-Sep	-0.58	-0.63
10-Nov	-0.72	0.29
11-Jan	-0.64	0.22
11-Mar	-1.37	0.06
11-Aug	1.65	0.1
11-Nov	1.01	-0.28
12-Jan	0.47	0.45
12-Mar	0.17	-0.21



nMDS Coordinates of Site CB		
Sample	X	Y
10-Sep	-0.03	0.54
10-Nov	0.19	0.73
11-Jan	0.39	-0.18
11-Mar	1.36	0.12
11-Aug	-1.86	0.02
11-Nov	-0.53	0.04
12-Jan	0.07	-1.06
12-Mar	0.41	-0.21



sites, CB and UB, were not significantly different, a phenomenon that also coincided with the outcome of the sweep data community structure. In addition, contrary to the hypothesis, reference sites 5 and 8 both showed significant differences in invertebrate community composition from before the fire to after and both had increases in species richness.

The deviations from the hypothesis could possibly be explained by looking at the placement of the sites in relation to the L-67 canal and levee and their individual habitat structure. All sites that had significant changes in invertebrate community composition (DB, 5, and 8) were marsh sites and far from large bodies of permanent water. Marshes usually have a large diversity of native species as well as a large size diversity of species. They have relatively shallow water depths usually averaging from 1.0 to 6.0 feet. Increased compartmentalization through the use of levees and drainage canals has decreased the overall water levels of the Everglades and has altered the pattern of water flow from the summer to winter months. Due this uneven distribution, any natural disturbances in the ecosystem such as droughts or fires are now occurring more frequently and severely. A prolonged drought in a wetland ecosystem that already has shallow water levels, and has a biotic community that is entirely dependent on water could drastically impact the health of the wetland community as a whole.

Therefore, it can be hypothesized that the marsh sites that had significant change in invertebrate community composition, with their delicate ecosystem diversity, had less chance to rebound from these disturbances due to greater distance from deep water refuges and had to adapt more to the conditions of the drought and also the fire in the case of DB. In the other two DPM sites, CB and UB, a canal site and a marsh site respectively; the invertebrate communities did not significantly change. Based on the conclusion made regarding the marsh sites, drainage canals in the Everglades not only cause the stress on marshes by removing water, they also have twice the water depth than marshes do, averaging around 12 feet. The aquatic community in the canal can be different from

that in the marsh, often having higher numbers of large organisms, such as adult largemouth bass and Florida gar. Canals not only have a larger supply of water to recover quickly from a drought, they also have little exposed vegetation and their depths provide refuge for certain animals in the case of a fire. Therefore, it is easy to see how the CB site was resilient to the fire. The UB site, north of the L-67c canal, is a marsh site. However, unlike the other marsh sites, it is close and directly upstream of the L-67c canal and the L-67c levee (150-300 meters away), which separates DB from CB and UB. The levee blocks water flow coming from the west (which prevents water flowing downstream from entering the DB site), yet another reason why the invertebrate community of DB changed after the natural disturbance. The UB site most likely didn't have a significant change in community structure due to its close proximity to the deepwater refuge of the L-67c canal. Additionally, it would have been easier to seek refuge in the canal for organisms in UB than DB, as only large or more agile invertebrates, such as crayfish, would be able to cross over from DB.

Densities of individually selected invertebrates—crayfish (Procambarus spp.), grass shrimp (Palaemonetes paludosus), and two types of dragonfly larvae: the Halloween pennant (Celithemis eponina) and the green darner (Anax junius)— were also compared before and after the fire in each site. The sites that varied significantly, DB, 5, and 8, all had the same trends regarding these four species. Crayfish and green darners increased in these marsh areas after the fire and Halloween pennants and grass shrimp both decreased. Crayfish are critical to the ecosystem; they are resilient to almost every disturbance, natural or anthropogenic, and are capable of adapting to most conditions and habitats in the everglades, which means they can live in both canals and marshes. Crayfish are the type of organisms that would thrive in the canal, which is mostly suited for large predators due to the more open space (not so structured with tall plants like saw grass). Crayfish are vital to the food web, but the dramatic increase in crayfish numbers in the marsh habitats suggests that the recovery time of the marsh habitats was not fast enough, and supports the idea that droughts are more detrimen-

tal to ecosystem composition when sheet flow is blocked. Green darners, unlike crayfish, are much less abundant in the sites surveyed but they did show an increase across all sites (when present); when they were caught, they were caught after the fire rather than before. This is most likely due to the clearing of sawgrass, which may allow these small predators to have more room to maneuver, and consequently a greater change of being caught in a throw trap. Grass shrimp are almost as abundant as crayfish, but unlike crayfish, may be more sensitive to water conditions and showed a unanimous decrease in every site. They mostly reside near the surface of the water, and are often clustered around or near sawgrass. The loss of sawgrass combined with the loss of water almost certainly contributed to their decrease in density. Halloween pennants are less abundant that grass shrimp, but they also decreased after the fire at all sites, for most of the same reasons as the grass shrimp.

Application

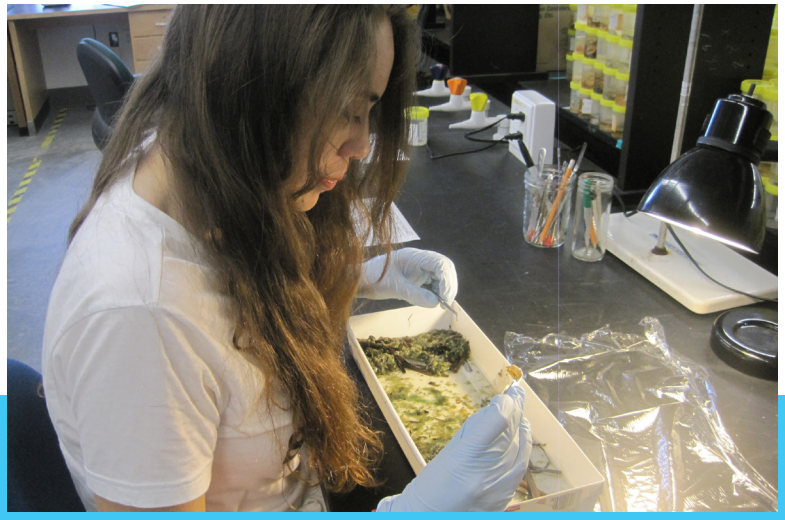
There are several important practical applications of this study:

The government is planning on spending more than $10.5 billion on the Comprehensive Everglades Restoration Plan (CERP), the largest hydrologic restoration project ever undertaken in the United States. It is expected to take more than 35 years to restore as much of the Florida Everglades to its natural state as possible. To assess the progress and success of CERP, ecosystem managers must have measurable goals and targets to track the expected responses from the Everglades ecosystem, including animal species responses to increased water levels, shifts in plant community composition, and changes in productivity patterns. The DECOMP project, an extension of CERP, is functioning as a test run for CERP's plans to remove levees, decompartmentalize the everglades, and restore historical hydrologic connectivity. The use of biological indicators to show the overall health of the ecosystem as a whole is crucial in determining if CERP's proceedings are having the desired effect on the aquatic community. The results of this study not only reinforce CERP's motives for removing canals, but it also provides useful information for how to deal with the possibility of natural disturbances elsewhere in Florida.

As of now, there are very few studies regarding the impact of natural fires on the composition and health of wetlands ecosystems. Wildfires are assumed by many ecologists to be mostly beneficial to terrestrial ecosystems, however there is little data on how wildfires affect areas such as the Everglades. Although fires have always occurred naturally in the everglades, after the compartmentalization, they may be occurring more frequently severely. In an ecosystem already deprived of historic water levels due to the anthropogenic addition of drainage canals and levees, natural disturbances can be more harmful as well. The results of this study suggest that disturbances like droughts and fires have the potential to be severely damaging to the structural cycles of wetlands ecosystems when combined with the presence of drainage canals and levees. This conclusion reinforces CERP's motive for restoring hydrologic connectivity in the Everglades and helps to justify the enormous federal expense of time and money that is going into CERP.

Consequently, this study also demonstrates how these natural disturbances can hinder restoration efforts as the June 2011 fire delayed DECOMP an entire year. Restoration efforts are not able to proceed as planned if there is a disturbance like this because all of their work and planning might have unintended effects on the newly changed ecosystem. Even though restoration is a year delayed, this study could be crucial for CERP and DECOMP because fires that clearly have an effect on the invertebrate community composition need to be taken into account before breaking down levees as planned.

Additionally, the dramatic increase in crayfish numbers in the marsh areas suggests that with the destruction of canals, crayfish numbers might continue to grow in the marsh. With this in mind, this could potentially provide a unique opportunity to help restore the Wood Stork, an endangered wetland species. Crayfish are a main source of food for wood storks and the reintroduction of these wading birds in marshes might also help balance the crayfish population.



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